A LITHIUM-BEARING CA,AL-RICH INCLUSION FROM THE CM-CHONDRITE COLD BOKKEVELD STUDIED BY TOF-SIMS AND CONVENTIONAL SIMS; **S. Schirmeyer[1], P. Hoppe[2], T. Stephan[1], A. Bischoff[1], and E. K. Jessberger[1]**, [1]Institut für Planetologie Wilhelm-Klemm-Str. 10, 48149 Münster, Germany; [2]Physikalisches Institut, Universität Bern, Sidlerstr.5, CH-3012 Bern, Switzerland.

Imaging time-of-flight secondary ion mass spectrometry (TOF-SIMS) is an excellent technique for the investigation of the micro-distribution of elements within different components of chondrites. We used this technique to study the elemental distribution of Li within several carbonaceous chondrites, because Li can be detected by TOF-SIMS with high sensitivity. In CM-chondrites Li-enrichments were exclusively found within Ca,Al-rich inclusions and mainly occur in the Fe-rich phyllosilicates. Since Li-enrichments have not been found within the Fe-rich phyllosilicates of the matrix, it is possible that those within CAIs were formed by alteration in a different environment. A nebular origin for the alteration of CAIs is suggested.

Analytical techniques: A CAI, discovered in a polished thin section of the CM-chondrite Cold Bokkeveld, was studied in detail by imaging TOF-SIMS, conventional SIMS, scanning electron microscopy (SEM), and electron microprobe techniques. High resolution TOF-SIMS images were obtained with the Ga primary ion source to discover the Li-bearing phases. For Li quantification and TOF-SIMS sensitivity determination Li was measured with a Cameca IMS3f ion microprobe using an O^- primary beam of 10 µm in diameter. As standards glass (NBS613), spodumene, and muscovite were analyzed (Table 1).

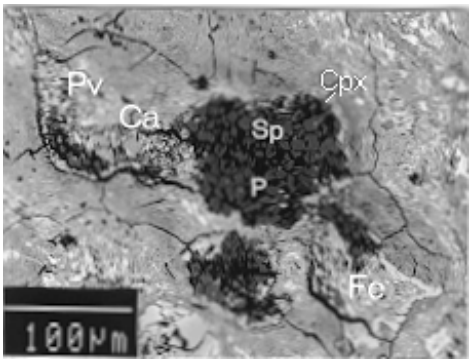
Results: The discovered Li-bearing CAI (Fig. 1), called "the cormorant" based on its outer shape, mainly consists of spinel. Most of the inclusion is surrounded by a Ca-pyroxene rim. Tiny perovskite grains were detected in the "neck" and "tail" regions. The occurrence of OH-bearing phases proves that this refractory inclusion was affected by aqueous alteration processes. These phases show a distinct mineralogy. Three Ca-bearing grains were identified as $Ca(OH)_2$ using imaging TOF-SIMS. The most important finding within the CAI is the discovery of Li-bearing Fe-phyllosilicates, which are sited in "neck" and "tail". Generally, they form irregulary shaped fibrous aggregates. In the "neck" they occur in a small rim between the interior spinel and the Ca-pyroxene rim. The Fe-phyllosilicate rim is interpreted to be an alteration product of melilite [1]. Chemical analyses of the Li-bearing Fe-phyllosilicates have been carried out by electron microprobe techniques (Table 2). The OH-bearing silicates are rich in FeO, Al_2O_3 and SiO_2, whereas the Ca-content is below 1 wt.%. The preliminary evaluation of TOF-SIMS spectra shows that the atomic Li/Si ratios range up to 175xCI (CI: 5.71×10^{-5};[2]). To obtain quantitative results the "tail", a part of the "neck", and the host rock close to the CAI were also examined by conventional SIMS (Table 1). Because of its small size it was impossible to measure the Li-contents of the Fe-phyllosilicate rim. The Li-abundances of the "tail-region" range from 360 to 740 ppm. In the "neck" 160 ppm were detected. In the host rock, which consists of similar Fe-phyllosilicates, we measured 3 ppm Li. The isotopic $^7Li/^6Li$ ratio of the Li-enriched phases does not show significant deviations from the cosmic value of 12.33 [2].

Discussion: CM-chondrites contain various components that have been altered by secondary processes. Some controversy exists about the time and environment of their formation. Metzler et al. [3] suggested that at least some aqueous phases were produced prior to the accretion of the final CM parent body. Browning et al. [4] developed an CM alteration scale, which correlates the alteration features of several CM-chondrites and supports the parent body alteration model. The results of our ion probe and TOF-SIMS studies of Fe-phyllosilicates, which occur in the CAI and in the host rock, show that Li is distributed heterogeneously. It can be ruled out that Li is a component of the precursor material, most likely melilite [5], [6]. Li was incorporated into the phyllosilicates during aqueous alteration processes. Due to the heterogeneous distribution of Li it is suggested that the Fe-phyllosilicates formed under different conditions in different environments. We suggest that the Li-bearing Fe-phyllosilicates are the result of alteration processes in the nebula prior to incorporation of the CAI into the meteorite parent body.

References : [1] Greenwood R.C., Lee M.R, Hutchison R. & Barber D.J. *Geochim. Cosmochim. Acta* **58**, 1913-1935 (1994); [2] Anders E. & Grevesse N. *Geochim. Cosmochim. Acta* **53**, 197-214 (1989); [3] Metzler K., Bischoff A. & Stöffler D. *Geochim. Cosmochim. Acta* **56**, 2873-2897 (1992); [4] Browning L. B., McSween H. Y. & Zolensky M. E. *Geochim. Cosmochim. Acta* **60**, 2621-2633 (1996); [5] Dreibus G., Spettel B. & Wänke H. *Proc. Lunar Sci. Conf.* **58**, 3383-3396 (1976); [6] Schirmeyer S., Bischoff A, Stephan T., and Jessberger E.K. *Meteoritics* **31** Supp., A123 (1996).

Fig. 1: Li-distribution within a Ca,Al-rich inclusion from Cold Bokkeveld; Li only occurs in Fe-rich phyllosilicates (Fe) particulary in the "tail" region. Other constituents of the CAI are spinel (Sp), perovskite (Pv), $Ca(OH)_2$ (Ca). The porous (P=porous) refractory inclusion is surrounded by a rim of Ca-pyroxene (Cpx).

a) SEM-BSE image



b) TOF-SIMS image showing $^7Li^+$-distribution

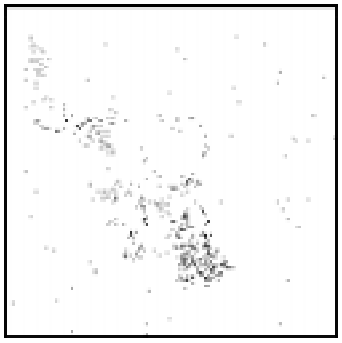


Table 1: Determined sensitivity e of Li^+ relative to Si^+ measured in different Li-bearing materials; Li-abundance and isotopic ratio measured in Fe-phyllosilicates occurring in host rock and CAI.

Table 2: Composition of Li-bearing Fe-phyllosilicates occurring in an CAI of the CM-chondrite Cold Bokkeveld. All data represent mean values in wt%; electron microprobe analyses.

Table 1:		
Sample	Sensitivity: e (Li^+)/e (Si^+)	$^7Li^+/^{30}Si^+$
NBS 613	5.90±0.67	0.106±0.012
Spodumene	5.58±0.12	82.6±1.8
Muscovite	4.40±1.03	0.0513±0.0120
Average	5.29±0.79	
Host rock	Li (ppm)±15%	$^7Li/^6Li$
COB001	2.53	11.8±0.2
COB002	3.31	12.1±0.1
COB003	3.13	11.8±0.2
CAI: "Tail"		
COB004	360	12.22±0.03
COB005	740	12.27±0.02
COB006	450	12.20±0.02
CAI: "Neck"		
COB007	160	12.19±0.04

Table 2:	Cold Bokkeveld
	Mean n=9; 1 sigma error
SiO_2	21.5±1.0
TiO_2	0.28±0.10
Al_2O_3	17.6±3.1
Cr_2O_3	0.04±0.03
FeO	31.5±3.9
MnO	0.21±0.03
MgO	11.3±1.7
CaO	0.61±0.11
Na_2O	0.28±0.07
K_2O	0.03±0.01
P_2O_5	0.02±0.01
NiO	0.06±0.03
SO_3	0.59±0.14
Total	84.0±2.1